Before the
Federal Communications Commission
Washington, D.C. 20554

In the Matter of	}	
	}	
Revision of Part 15 of the Commission's	}	
Rules Regarding Ultra-Wideband	}	ET Docket No. 98-153
Transmission Systems	}	

<u>Reply Comments of Multispectral Solutions, Inc.</u>

Multispectral Solutions, Inc. (MSSI) is pleased to submit these further reply comments in response to the Notice of Proposed Rule Making (NPRM), FCC 00-163, in the above referenced proceeding. These comments are provided as additional clarification to MSSI's statement that the FCC should consider a limit on the maximum permissible pulse repetition frequency (PRF), or pulse rate, for an ultra wideband (UWB) emission in order to prevent harmful interference to existing services.

As noted by the NTIA, and pointed out in MSSI's most recent submission dated 22 February 2001, high PRF UWB emissions have the highest likelihood of causing serious interference to existing systems and services when operated within the same frequency band.

Several UWB advocates have proposed the development of commercial systems using extremely high pulse (and data) rates, yet these same proponents also state that such systems will cause no harmful interference:

Fantasma Networks

> *"Fantasma's first generation products will support data rates up to 60 Mbps at a distance of 100ft (30 meters)."*[1]
>
> *"The NTIA study shows that ultra-wideband communications technologies can operate in a broad range of frequencies above 2 GHz, even with the compounded 'worst case' assumptions used in their analysis," said Dr. Roberto Aiello, Chief Technology Officer of Fantasma Networks. "Using the NTIA data and methods as a foundation for our analysis, we have found that the opportunity to share frequencies with existing spectrum users is even brighter than NTIA envisioned," remarked Aiello.*[2]

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1 http://www.fantasma.net

2 "Fantasma Networks' Report to FCC Demonstrates that UWB Causes No Harmful Interference to Spectrum Users Above 2 GHz," Press Release, 23 February 2001.

XtremeSpectrum, Inc.

> *"The firm has a prototype that transmits data at 50 megabits a second, and it will soon demonstrate a model that operates at 100 megabits per second, Rofheart said. 'We can deliver products that deliver extraordinarily high rates of data using very low power,' he said"*[3]

> *"Much of the opposition to ultra-wideband greatly overstates the potential for interference, perhaps in part because commenters, lacking hard information, tend to assume the worst."*[4]

Time Domain Corporation

> *"Time Domain hopes to see the first home wireless networking products released in early 2002, operating at 40 Mbps. Within four years, it expects to boost data rates to 1 Gigabit per second …"*[5]

> *"We are confident tests will show UWB will not show harmful interference. If [interference] is shown, we will take steps to mitigate that."*[6]

While it is certainly true that Government and military interest in UWB systems originally stemmed from its low probability of intercept (and, thus, low probability of interference) characteristics, this was not a truism for all forms of short pulse transmissions. Indeed, the higher the data rate (and, hence, the higher the resultant pulse duty cycle), the more likely these emissions were capable of being intercepted and cause serious interference to other systems.

This is easily seen by way of the following example. Figure 1 illustrates the results of a MATLAB simulation in which a 10 microsecond burst from a 1 GHz bandwidth UWB waveform (centered at 4 GHz) is received by a 1 MHz RF bandwidth receiver operating over the same frequency range. The measured output voltage at the receiver RF stage output terminals is shown as a function of UWB emitter pulse repetition frequency. In this example, PRFs of 1 Mpps, 10 Mpps and 100 Mpps are shown. As expected from theory (cf. Appendix A), whenever the PRF exceeds the victim receiver's RF bandwidth, the total power injected into the receiver increases as the *square* of the PRF. Hence, a 100 Mpps UWB waveform is 10,000 times worse than a 1 Mpps UWB waveform. This effect is strongly evident from the Figure.

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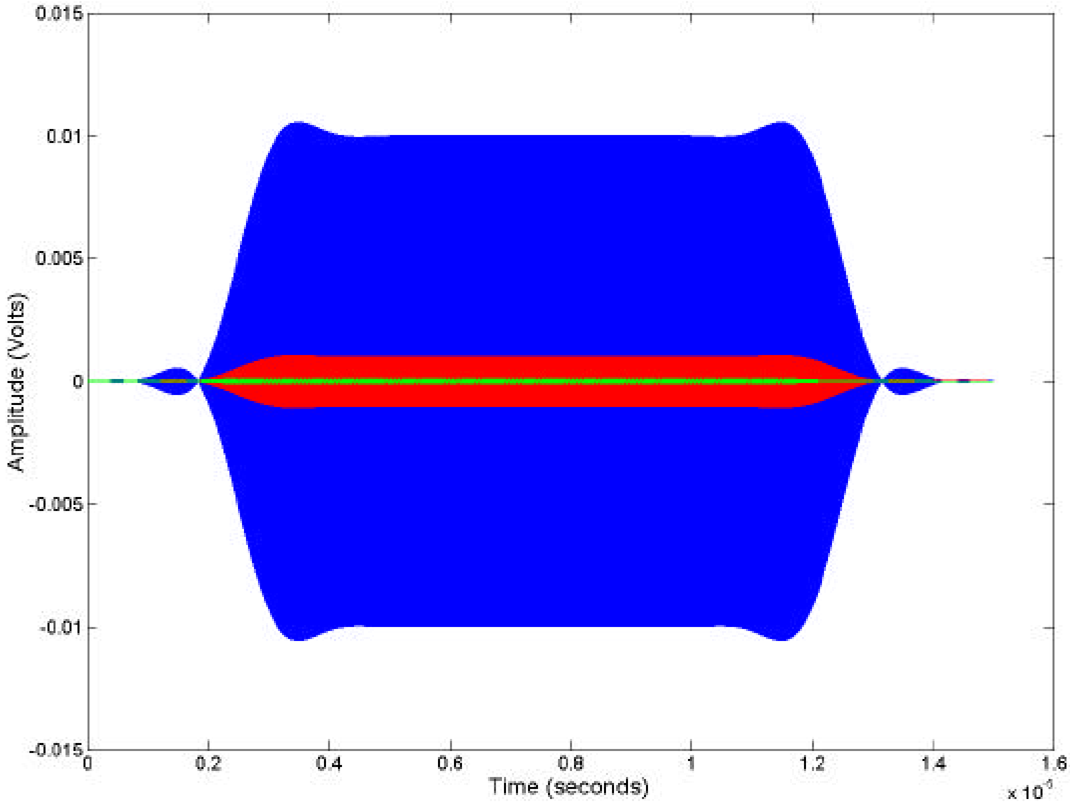
[3] Van, John, "Radio's Future Superpowers," *chicagotribune.com*, 23 October 2000.

[4] Reply Comments of XtremeSpectrum, Inc., Ultra-Wideband transmission Systems, ET Docket 98-153, 27 October 2000.

[5] Kahney, Leander, "Personal Radar on the Horizon," *WiredNews*, 16 November 2000, http://www.wired.com/news/technology/0,1282,40210,00.html.

[6] Comments by Mr. Jeff Ross, Time Domain, quoted in Hirschman, Carolyn, "FCC debates UWB deployment," *Telephony*, 27 November 2000, p. 140.



Blue: 10 µs Burst of 100 Mpps UWB Waveform
Red: Burst of 10 Mpps UWB Waveform
Green: Burst of 1 Mpps UWB Waveform

Figure 1. Impact of Pulse Repetition Frequency (PRF) on Measured Output Voltage at Victim Receiver.

The above example points out that high PRF UWB systems can indeed produce very large output voltages in a narrowband victim receiver, even when the bandwidth of the UWB system is spread over GHz of instantaneous bandwidth.

Given the recent test results from Stanford/DOT[7] and the NTIA[8], it appears that a PRF cutoff of 10 Mpps is adequate to protect existing wireless services.

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7 "Potential Interference to GPS from UWB Transmitters, Test Results. Phase 1A: Accuracy and Loss-of-Lock testing for Aviation Receivers," M. Luo, D. Akos, S. Pullen and P.Enge, Stanford University, 26 October 2000.

8 "The Temporal and Spectral Characteristics of Ultrawideband Signals," William A. Kissick, editor, NTIA Report 01-383, January 2001 (http://www.its.bldrdoc.gov/pub/ntia-rpt/01-383/).

"Assessment of Compatibility Between Ultrawideband Devices and Selected Federal Systems," Brunson, L.K. et al., NTIA Special Publication 01-43, January 2001 (http://www.ntia.doc.gov/osmhome/reports/uwb/uwb.pdf).

Conclusion

The FCC and NTIA are contemplating the unlicensed use of UWB systems at frequencies above 3.1 GHz. However, some of these frequencies overlap existing Part 15 restricted bands; and some of these restricted bands are utilized for critical aeronautical safety systems.[9] As shown by the NTIA and in the above analysis, high PRF UWB emitters (particularly those with PRFs greater than 10 Mpps) can indeed create interference to existing services.

MSSI respectfully recommends that, in order to enable the introduction of UWB technology with the least potential impact on existing systems:

1. The FCC should consider placing an upper bound of 10 Mpps on the pulse repetition frequency (PRF) of any UWB emitter operating within existing restricted bands above 3.1 GHz; and,

2. The FCC should permit higher PRF UWB emissions in any current non-restricted band above 3.1 GHz (e.g., 5.46 to 7.25 GHz).

Finally, we agree with the NTIA that UWB operation below 3.1 GHz is very problematic. Thus, MSSI further recommends that UWB operation in frequencies below 3.1 GHz should be permitted on a licensed basis only.

Respectfully submitted,

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[9] See "Supplemental Comments of Rockwell Collins, Inc. Regarding NTIA's UWB Analysis Reports", dated 1 March 2001.

Appendix A
Received Power in Victim Receiver vs. Pulse Repetition Frequency of UWB Emitter

This Appendix briefly discusses the effect of UWB pulse repetition frequency (PRF) on the measured voltage at the output of the front end filter in a victim receiver with bandwidth B_{RF}. The analysis is broken down into two parts: PRF > B_{RF} and PRF < B_{RF}.

PRF < B_{RF}

First of all, note that for a filter of bandwidth W, the impulse response (from Fourier transform theory) has a duration of approximately 1/W. Thus, for example, a 1 MHz bandwidth filter has an impulse response of roughly 1 microsecond. Now, if PRF < B_{RF}, the interarrival time between UWB pulses (given by 1/PRF) is greater than the impulse response duration of the filter ($1/B_{RF}$). In this case, the filter output due to one UWB pulse has essentially died down before the next pulse hits the filter input. That is, there are no cumulative effects from pulse responses adding within the filter.

For a baseband rectangular filter of bandwidth W, the impulse response is given by

$$h_W(t) = W\,\frac{\sin(pWt)}{pWt}.$$

(The results can be readily translated to an arbitrary RF frequency by heterodyning the resultant impulse response.)

Thus, for an impulse bandwidth B_{UWB} and a victim receiver bandwidth B_{RF}, the ratio of the input voltage V_{IN} (at the victim receiver input terminals) to the received output voltage V_{OUT} (after RF filtering) is given by

$$\frac{V_{OUT}}{V_{IN}} = \frac{B_{RF}\,\dfrac{\sin(pB_{RF}t)}{pB_{RF}t}}{B_{UWB}\,\dfrac{\sin(pB_{UWB}t)}{pB_{UWB}t}}$$

which takes on a maximum value of B_{RF}/B_{UWB} when t=0.

Hence, in terms of incident and received power levels

$$\max\left(\frac{P_{OUT}}{P_{IN}}\right) = \left(\frac{B_{RF}}{B_{UWB}}\right)^2$$

independent of PRF.

PRF > B_{RF}

Now, for PRF > B_{RF}, more than one UWB pulse is present within the filter impulse response time. In general, there are approximately

$$N \approx \frac{PRF}{B_{RF}}$$

pulses present during impulse response duration $1/B_{RF}$. As these pulses add within the filter, the total output voltage is roughly N times greater than the above case. (The analysis here is heuristic, but can be made rigorous by utilizing Fourier analysis techniques.)

Thus, in this case,

$$\max\left(\frac{P_{OUT}}{P_{IN}}\right) = \left(\frac{B_{RF}}{B_{UWB}}\right)^2 N^2 \approx \left(\frac{B_{RF}}{B_{UWB}}\right)^2 \left(\frac{PRF}{B_{RF}}\right)^2 = \left(\frac{PRF}{B_{UWB}}\right)^2 .$$

From this result it is seen that the voltage at the output of the victim receiver's RF filter increases as the *square* of the UWB pulse repetition frequency.

The above results were also confirmed by simulation and by recent NTIA tests.